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Sea water air conditioning (SWAC) at Naval Base Guam: Cost-benefit analysis and acquisition strategy

16 March 2015

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ACQUISITION RESEARCH PROGRAM
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SEA WATER AIR CONDITIONING (SWAC) AT NAVAL BASE GUAM: COST-BENEIT ANALYSIS AND ACQUISITION STRATEGY

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The purposes of this research are to determine whether it is financially feasible and attractive to install sea water air conditioning (SWAC) at Naval Base (NB) Guam, which the Naval Facilities Engineering Command currently deems to be true; to develop an acquisition strategy that NB Guam would be able to use to procure a SWAC system; and to identify any environmental obstacles associated with installing a SWAC system at NB Guam. This includes environmental impact studies and potential long-term schedule effects of environmental research. This research provides the analytic underpinning for the SWAC-driven reduction of electricity consumption at a significant number of naval facilities, and it provides a significant contribution towards meeting the Secretary of the Navy's renewable energy goals.

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LIST OF ACRONYMS AND ABBREVIATIONS

AFB	air force base
CBA	cost benefit analysis
CWA	Clean Water Act
DOD	Department of Defense
EA	environmental assessment
ECIP	Energy Conservation Investment Program
EFH	essential fish habitat
EIS	environmental impact statement
EPS	Environmental Protection Agency
ESA	Endangered Species Act
ESCO	energy service company
ESPC	energy savings performance contract
FONSI	finding of no significant impact
FWS	Fish and Wildlife Service
GEPA	Guam Environmental Protection Agency
GPA	Guam Power Authority
IPT	integrated product team
MILCON	military construction
NAVFAC	Naval Facilities Engineering Command
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NB	naval base
MSL	mean sea level
RAC	risk assessment code
ROD	record of decision
SHPO	State Historic Preservation Office
STEP-R	strategic environmental planning roadmap
SWAC	sea water air conditioning

TRL	technology readiness level
UESC	utility energy service contract
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
UXO	unexploded ordinance
USFWS	U.S. Fish and Wildlife Service
WOD13	World Ocean Atlas 2013
WPRFMC	Western Pacific Regional Fishery Management Council

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I. SEA WATER AIR CONDITIONING

As the twenty-first century progresses, the Pacific Ocean increases in strategic importance to the United States. Political and military tensions rise once again in a vast, long-dormant oceanic domain geostrategically unchallenged since World War II. America is pivoting to the Pacific, shifting more operational units to an increasing number of duty stations scattered across the region. Some inactive bases will be renovated and reactivated, new training areas will be constructed, and many bases in once-familiar locations will be shared with partner nations through joint-use agreements. As a rising Asian power, China seeks strategic inroads and access across the Western Pacific (see Figure 1), the new strategic reality confronts a Department of Defense (DOD) facing fiscal austerity. Resources are at a premium in a fiscally challenging environment. In an era when the DOD must do more with less, the need to maximize efficiency of resources in general and those allocated to the Pacific in particular is vital. Efficient allocation of scarce resources will likely be an important component in determining the outcome of a future Pacific confrontation.

Figure 1. The Western Pacific (from United States Naval Institute, 2011)

Maximizing the efficiency of DOD resources in the Pacific will enhance the strategic and operational effectiveness of the pivot. Conserving resources at shore installations scattered across the Pacific will provide more resources for critical operational units. Renewable energy is a recognized effective means of conservation. The present is an era of significant advancement in renewable energy capabilities, and the DOD has ample opportunity to make use of new technologies to conserve resources. In the Pacific, renewable energy employment would also increase the operational independence of isolated installations by reducing the amount of fuel that the DOD must ship across long sea lines of communication, which may one day be contested.

A. CONVENTIONAL VERSUS SEA WATER AIR CONDITIONING

The DOD already pursues several renewable energy options for its bases, such as wind and solar energy. However, ample room remains for new renewable technologies

and cost savings at shore installations (Sinclair, 2013). In conventional air conditioning, a relatively large electrical load is used to cool air or refrigerant to facilitate the transfer of heat from a building to the cooling medium. Large systems are expensive and employ cooling towers, chillers, compressors, and pumps. One of the largest costs at installations in tropical climes is air conditioning. High local electricity prices at many isolated tropical bases further amplify the cost of conventional air conditioning (Sinclair et al., 2011). Conventional air conditioning, however, is no longer the only choice for many installations. Sea water air conditioning (SWAC) is a rarely discussed but perfectly suited technology for bases in the Pacific and other tropical climes; SWAC could trigger substantial shore installation cost savings (Sinclair, 2013). Table 1 illustrates some of the projected savings of installing SWAC at appropriately sited tropical bases. The table uses the 2013 real discount rate of three percent mandated by the Department of Energy for projects related to renewable energy resources (Sinclair, 2013).

Table 1. SWAC Savings in the Tropics (after Sinclair, 2013)

Naval Facility:	**A/C Load (tons)**	**Elec. Saved (kWh/yr)**	**Elec. Cost (/kWh)**	**Pipeline Length**	**Capital Cost**	**Simple/ 3% Discounted Payback (Years)**
Diego Garcia	4,000	19.3M	$.501	2.2 miles	$158M	14/19
GTMO	6,100	27.5M	$.273	1.1 miles	$151M	16/21
NB Guam	8,400	32.6M	$.272	2.5 miles	$168M	16/
Andersen AFB	12,000	46.6M	$.272	1.9 miles	$216M	17/
JBPHH	28,600		$.238	4.5 miles	$360M	17/25

Sea water air conditioning, in contrast to conventional air conditioning, uses a naturally cold medium to remove heat from buildings instead of employing electricity to cool the medium first. The SWAC cooling medium is deep cold sea water. In a SWAC system, a deep water intake pipe draws in deep cold sea water to a cooling station, which houses electrical pumps—for moving the water—and heat exchangers. The heat exchangers transfer heat from a closed loop chill water distribution system to the sea

water loop. The warm sea water is discharged from a shallow warm sea water outtake pipe at a depth matching ambient ocean temperature. The closed loop chilled water distribution acts as a district cooling loop, which provides the air conditioning medium for a large group of buildings, such as a naval base (Sinclair et al., 2011). Figure 2 provides a basic outline of SWAC operation.

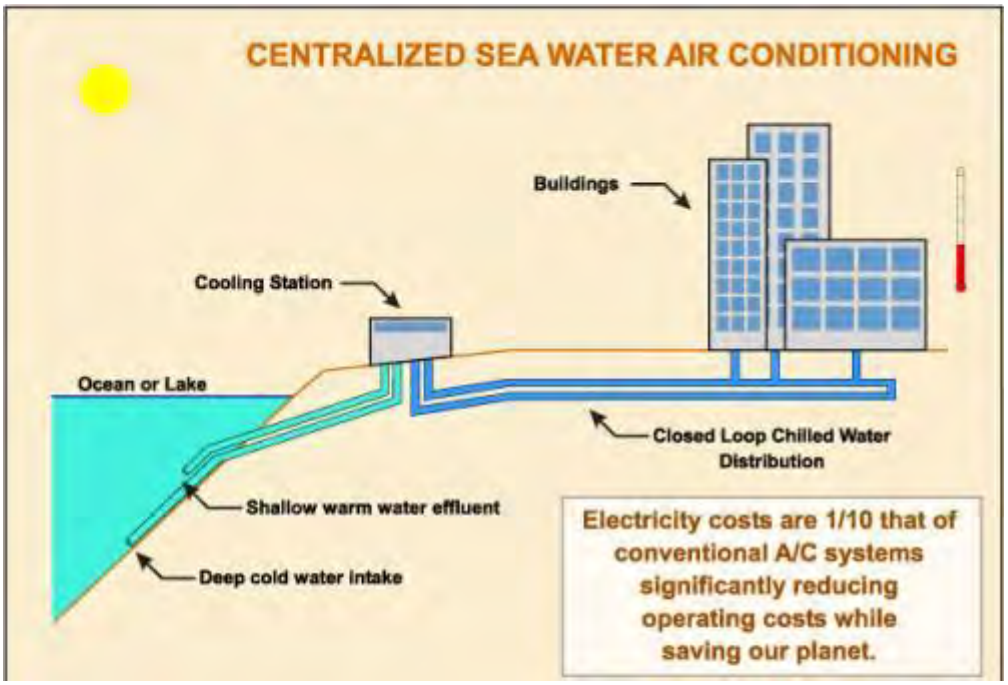

Figure 2. Centralized Sea Water Air Conditioning (from Makai Ocean Engineering, 2014)

B. NAVAL BASE GUAM

Naval Base (NB) Guam is ideally suited for SWAC. Guam is a high coral island surrounded by a fringing reef, beyond which there is a precipitous drop to the deep ocean floor. This provides NB Guam with easy, short-distance access to deep, cold sea water. Guam also has a high localized cost of electricity, which is crucial to providing a substantial enough return on investment on renewable energy projects to meet payback period requirements (Sinclair et al., 2011). The authors selected Guam as a first choice for SWAC because it is a highly strategic yet isolated asset that remains dependent on imported diesel to provide power to the entire island, including the military bases.

SWAC, if implemented, would represent a substantial step in improving the energy affordability, security, and independence of DOD installations on Guam and in the Pacific.

There is a security dimension to installing SWAC at NB Guam, which is less discussed than its financial benefits. It is closely linked to energy independence. In the pre-World War II era, Guam served as a critical supply conduit to American forces in the Philippines and Asia. In the present, Guam once again executes this strategic role. America's logistical capabilities are finite. The less diesel the Armed Forces expend at bases in the Central Pacific, the more shipping capacity there will be available to support critical operations. Developing a lighter shore energy footprint through technologies such as SWAC could make the difference in the next major Pacific conflict; increased energy independence will only make America's far-flung bases more self-reliant and more defensible. Figure 3 illustrates DOD installations in Guam.

Figure 3. Guam DOD Installations (from United States Navy, n.d.)

Because the Navy has never before pursued SWAC at one of its installations, significant questions must be addressed before any project moves forward. The authors divide these significant questions into three broad areas of study. The first involves a cost-benefit analysis (CBA), which builds on previous work by examining unaddressed issues, such as the need for a SWAC backup system on Guam due to the perpetual typhoon threat and the potential cost of said system. The CBA also includes input from energy management experts at NB Guam. The second area of study is the environmental

permitting process. The authors deal with Guam-specific environmental issues and provide a thorough look at how the permitting process might look for the Navy's first SWAC system. The third broad area of study involves SWAC acquisition. The authors determine the most effective vehicle for SWAC acquisition and then construct a combined SWAC timeline, which includes both the projected environmental permitting timeline and the projected acquisition timeline.

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II. TECHNICAL FEASIBILITY OF SWAC ON GUAM

Although SWAC has never been used by the Navy, it has been in commercial use since at least 1983 with individual SWAC systems installed all over the world, including locations in Kona, Hawaii; Stockholm, Sweden; Cornell University, New York; and Toronto, Canada. The air conditioning capacity of each of these locations varies from 50 tons at the Natural Energy Laboratory of Hawaii Facility in Kona to greater than 100,000 tons at the facility in Stockholm (War, 2011, p. 6). For reference, one ton of air conditioning is defined as the cooling power provided by one ton of ice during a 24-hour period. Based on the success of the technology in over seven different sea water locations (War, 2011), the authors believe that SWAC is at the highest technology readiness level (TRL), TRL 9, as shown in the TRL definitions in Table 2.

Table 2. Technology Readiness Level Definitions (after Assistant Secretary of Defense for Research and Engineering, 2011)

Technology Readiness Level	Description
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system.
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment.
6. System/subsystem model or prototype demonstration in a	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant

Technology Readiness Level	Description
relevant environment.	environment. Represents a major step up in a technology's demonstrated readiness.
7. System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space.
8. Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development.
9. Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation.

Makai Ocean Engineering, Inc., one of the world leaders in developing SWAC systems (War, 2011), listed the criteria that help determine the feasibility of a potential SWAC installation location. The top three of these criteria are the distance to offshore cold water, the size of the air conditioning load, and the percent utilization of the air conditioning system. The subsequent paragraphs explore how NB Guam meets these criteria.

A. DISTANCE TO OFFSHORE COLD WATER

As an island in the western Pacific, Guam has access to a plentiful supply of offshore cold water. Ocean temperature data taken from *World Ocean Atlas 2013* (WOD13) verifies that the ocean temperature offshore from Guam reaches the necessary 43°F. Figure 4, a depth versus temperature chart created from the data in WOD13, shows that the required temperature is reached at approximately 525 meters below the ocean surface. However, the exact depth needed is discussed further in a later chapter.

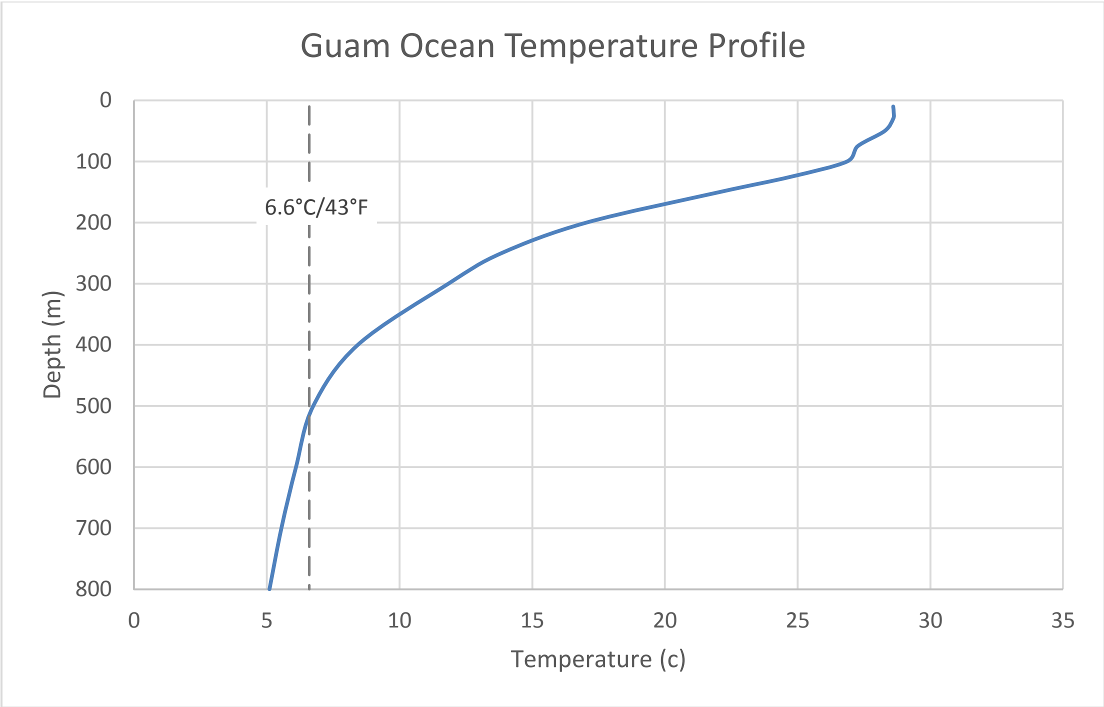

Figure 4. Guam Ocean Temperature Profile (after Locarnini et al., 2013)

B. SIZE OF THE AIR CONDITIONING LOAD

Another characteristic in deciding the feasibility of installing a SWAC system is the size of the air conditioning load. Currently, NB Guam has an 8,382-ton concentrated air conditioning load (CH2M Hill, Clark-Nexson, & Hatch Mott MacDonald, 2013). According to War's (2011) definition of the necessary load as one greater than 1,000 tons, this load is more than sufficient.

C. PERCENT UTILIZATION OF THE AIR CONDITIONING SYSTEM

Also important to a SWAC system's feasibility is how often the air conditioning system is utilized. The average temperature in Guam is 81.5°F with average highs ranging from 87.9°F in May and June to an average low of 75.0°F in February. Figure 5 depicts this data (Tiyan Weather Forecast Office, 2014).

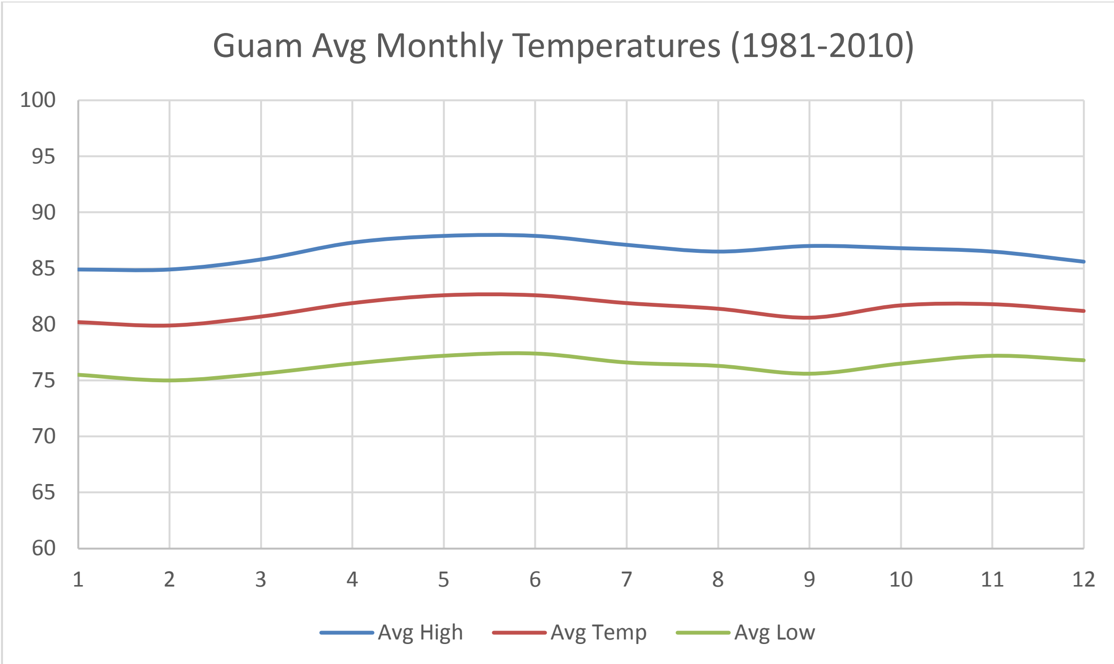

Figure 5. Guam Average Monthly Temperatures (after Tiyan Weather Forecast Office, 2013a–d, 2014a–h)

Currently, the air conditioning temperature points for buildings on NB Guam are set based on the type of usage in the building and when the building is usually occupied. These temperature points vary from a low of 70°F in most occupied buildings to a high of 78°F in unoccupied mechanical buildings (CH2M Hill et al., 2013). These air conditioning settings fall well below the average highs and mostly below the average lows for Guam year round. Due to the occupied air conditioning settings being well below the average high temperatures and the unoccupied temperature setting being just under the average low temperatures, the authors assume that the current air conditioning systems run almost 24 hours per day, all year-round. Therefore, NB Guam's proximity to cool sea water, the large size of the current air conditioning load, and the high utilization of the current system make the base an ideal location for the installation of SWAC.

III. SWAC ENVIRONMENTAL REQUIREMENTS OVERVIEW

The environmental permitting and impact evaluation phase of SWAC development is expected to be time-consuming and rigorous. The construction of SWAC involved in this proposal entails sending a pipe offshore to pull in cold ocean water from an estimated depth of 700 meters, and then having it returned nearby to a depth where the outflow is at the same ambient temperature, thought to be about 300 meters. These pipes will run to a chilling station, which also must be constructed. Extensive piping and other land construction must also be completed. This series of actions must be approved by several local and federal entities, and is expected to be one of the most time-consuming parts of the SWAC implementation process; from start to finish, the environmental permitting process and evaluation is expected to take somewhere between two and three years to complete, with an estimated price tag of $2.7 million. This is all shown in Table 3.

The Naval Facilities Engineering Command (NAVFAC) has already carried out an extensive feasibility study on this subject, submitting a timeline for the project in its 2011 report (see Table 4). The site that the NAVFAC has chosen on base as the best location for this system is the Orote Landfill site, which offers easy access to the best aquatic topography for SWAC that will not significantly hinder navigation.

Table 3. Estimated Environmental Permitting Costs (after Sinclair et al., 2011)

Action	Budget ($)	Remarks
National Environmental Policy Act (NEPA) Document	1,914,200	Starting costs plus EIS
Permitting	178,000	
Studies	659,500	
Total	2,691,700	

Table 4. NAVFAC Notational Permitting Schedule (after Sinclair et al., 2011)

1. Action Scoping—Length of time is 5 months (1st to 5th month)
a. Internal Scoping
i. Action Proponent
ii. Public Affairs
iii. Navy Command
iv. STEP-R (Strategic Environmental Planning Roadmap)
v. Preliminary System Design
b. NEPA Notification Letter
2. Agency and Regulatory Involvement—25 months (2nd to 27th month)
a. Cause and Effect Planning
b. Elected Officials and Regulatory Agencies
c. Siting and Data Availability
3. Public Involvement—6 months (8th to 14th month)
a. Public Scoping
4. Environmental Impact Analysis—20 months (3rd to 23rd month)
a. Purpose and Need
b. Proposed Action
c. Affected Area
i. Current condition of affected area
d. Impact Assessment
i. Effects of proposed action on the environment
ii. Regulatory Compliance
iii. Conservation Measures
iv. Mitigation Measures
5. Compliance Package—23 months (7th to 30th Month)
a. System Operation
b. Permit and Consultation Submittals
i. ESA section 7 Informal Consultation

ii. Coastal Zone Management Act- Negative Determination
Iii. RHA Section 10 Permit
iv. NPDES Permit
v. NHPA Section 106 Consultation
vi. Mitigation Plan
vii. USCG Coordination
c. Final Draft EA/EIS Submittal
d. Preliminary System Design
6. Product/Output
a. Final Finding of No Significant Impact/Record of Decision
b. System Fabrication
c. System Installation

The NAVFAC research to this point indicates that this timeline is substantially correct, assuming, as this outline does, that the environmental assessment comes back with a finding of no significant impact (FONSI). If that is not the outcome of the assessment, and an environmental impact statement (EIS) is required, the timeline will be extended by years, as is explained further in this chapter.

There are, as noted in Table 4, numerous permits and reports that must be prepared and submitted in order to construct the SWAC system at NB Guam. Strictly from a permitting perspective, the following requirements will need to be addressed in writing on a federal level.

The U.S. Army Corps of Engineers (USACE) must issue a permit in accordance with section 10 of the amended Rivers and Harbors Act of 1899. This regulation makes it illegal to discharge any material into an ocean or river that may be construed as refuse. Although the SWAC water outflow should be contaminant free, it is still flowing into a U.S.-controlled body of water, so this act must be addressed (Environmental Protection Agency [EPA], 2012a).

The U.S. EPA requires a permit under section 402 of the Clean Water Act (CWA). This permit would set up the reporting requirements for the SWAC discharge. Similarly, the CWA requires under section 316 that a permit be submitted concerning the SWAC intake (EPA, 2012c). Further pursuant to the CWA, section 404 of the CWA requires a permit for the dredging or fill operations taking place in navigable waters of the United States. This is usually completed through the USACE vice the U.S. EPA (EPA, 2012d).

From a local permitting point of view, the following permits would be required. The Guam Environmental Protection Agency (GEPA) has been given the charge of some of the island's oversight from the federal EPA, namely sections 303 and 401 of the CWA. Section 303 deals with water quality standards, and section 401 deals with water quality certification. Permitting under section 401 may be rendered inconsequential if, as is planned, the discharge water is the same temperature as the ambient water at that depth (EPA, 2012a, 2012b).

In addition to the above written permits needed to complete construction of the project, further consultation and negotiation will be necessary in a variety of other ways. The U. S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), and National Marine Fisheries Service (NMFS) may each require informal consultation under section 7 of the Endangered Species Act (ESA). The Department of the Interior may need to be consulted on this matter, under the same section, as well (Fish and Wildlife Service [FWS], 2013).

The U. S. Coast Guard (USCG) must be consulted as to the impact that the SWAC pipes will have on local maritime navigation. These impacts, though expected to be slight or nonexistent, will need to be included in the publication of "Local Notices to Mariners" (USCG, 2011).

The Guam Historic Resources Division/State Historic Preservation Office (SHPO) may need to be consulted if the space used for the chiller building or other infrastructure happens to be on protected or historically significant land. There is also the

chance of an artifact or item of historical import being unearthed during construction, in which case the SHPO would also need to be notified.

The Guam Department of Agriculture will possibly require a consultation about what aquacultural side effects may come about from this venture. There is an advertised benefit to SWAC development that touts its ability to harvest nutrients from the water that it cycles through its chiller. Any benefits derived from this could turn out to be highly helpful in making the case to implement SWAC on NB Guam.

Consultation with the NOAA, NMFS, and U.S. Fish and Wildlife Service (USFWS) will all be required under section 7 of the ESA with regards to any endangered species or sensitive wildlife habitats that may be affected by the construction of the SWAC system. Consultation will also likely be required with the Western Pacific Regional Fishery Management Council (WPRFMC) due to the Magnuson–Stevens Fishery Act of 1976 that provides the jurisdiction in Guam's waters with regard to impacts on commercial fishing (NMFS, 1996).

Consultation with NOAA on the subject of the island's nearby coral reefs should also be carried out to ensure that construction of the in-water portion of the SWAC system does not harm the reefs or interfere significantly with their growth season. This consultation would be in accordance with the Coral Reef Protection Act (NOAA, 2000).

A. PROPOSED ACTION

The proposed action involves, as noted previously, laying a pipeline with an aquatic input and output to and from a land-based chilling station to a specified offshore depth, likely to be about 700 meters for the intake and 300 meters for the outflow. These depths allow sufficiently cold water to be pulled into the system and for the returned water to be close to the temperature of the surrounding depth. In addition to the chiller building, there will also be an amount of on-land construction to fabricate ducting, pipes, and air conditioning infrastructure in open air and in various on-base buildings. The pipe itself will have some impact on the water it is placed in, although the impact will, by design, be as small as possible. This process, as mentioned, will entail a fairly intensive environmental investigation and permitting process. The long-term environmental

benefits of this action will involve the reduced reliance on the Guam power grid, which is powered by diesel turbines, and the lower carbon emissions that will accompany such a transition.

1. Proposed Alternative Action

The authors know of no alternative action planned for NB Guam with regards to reducing its air conditioning load through further green technologies, apart from rationing energy usage on the base.

2. Effects of No Action Taken

The costs of inaction have already been discussed, but in short, it would mean complete reliance on Guam's electrical grid to maintain the air conditioning levels on the base. This leaves a large part of NB Guam's operating costs dependent on what it costs the local power authority to purchase and burn diesel fuel, since that fuel generates the majority of the island's power generation. Over the projected 25-year life cycle of the SWAC system, the operational costs are projected to be much lower over the long run than the status quo, which is investigated in depth in a later chapter. In addition, the operation of SWAC is designed to be less power intensive and nearly independent of changes in the costs of energy feed stocks. An in-depth review of the likely economic impacts of weaning NB Guam's reliance on the local energy grid for air conditioning is discussed in a later chapter. The environmental benefits of burning less diesel fuel will also be significant over a long time period.

B. ENVIRONMENTAL IMPACT ASSESSMENT

Not yet discussed are the anticipated environmental impact studies that will be required to construct the SWAC system. Permitting and large-scale environmental study are vastly different exercises, and the studies are the part of the environmental vetting process that takes the most time and effort.

The National Environmental Protection Act of 1969 is the legislation that holds influence on whether or not the environmental impacts of an action are acceptable or not to the federal government. In compliance with this law, an environmental assessment

(EA) would have to be completed, and an EIS would possibly have to be done. Both the EA and the EIS would have to be done before the start of SWAC construction on Guam, as Table 4 prepared by the NAVFAC shows (Sinclair et al., 2011).

If it were determined that the SWAC system could be accomplished without significant environmental impact, only the EA would be required. An EA takes less time to produce, because it has a more streamlined set of requirements. One has only to take an assessment of the environmental impact of an action, and that leads to a determination about whether or not an EIS is required. If a FONSI is reached with an EA, than the project can be considered to have passed the environmental requirements. In this case, an EA can be usually be completed between 12 and 24 months. Alternatively, if a FONSI is not reached, an EIS must be prepared. The EIS cost and timeline can vary drastically. This, again is by design. An EIS mandates an in-depth review of the scope of all anticipated environmental impacts, and an on-the-record public review and input session, followed by a record of decision (ROD). It is assumed, given the prospective scope of the operation, that an EIS will be required for this project. If this proves true, the EIS can be done simultaneously alongside the permitting and various other requirements that must be fulfilled. As noted in Table 4, the EIS process is estimated to take between two and three years to complete.

It should be noted that the EA and EIS will likely focus on actions taken concerning the surrounding waters much more than the land-based construction. The environmental permitting process detailed above places heavy emphasis on examination of the area’s waters. The terrestrial portion of the project is expected to take place on land that is not considered overly environmentally sensitive, although the majority of the pipe will be laid underground. Even so, the piping and construction of the chiller building are far more routine for naval construction than laying a two-headed pipe array into the near offshore depths.

1. Anticipated Impacts on Surrounding Aquatic Environment

As previously mentioned, the majority of environmental permitting is going to deal with the waters that the SWAC piping is going to be submerged in. It is therefore

worthwhile to examine what the construction's long term impacts may be, and why the concerns exist as they do.

Water quality around Naval Base Guam is not expected to be affected adversely by the installation of a SWAC system. Drinking water, wastewater, storm water and ground water are all expected to be unaffected, although there could possibly be effects on the coastal waters near the intake and outflow piping. Further study on this will likely be needed, so the first step will be to establish a baseline of the affected area, in accordance with the CWA. This will be a starting point for such factors as the area's nutrient levels, and the plan for completion will be outlined by the U.S. EPA or the Guam EPA. Ocean currents must also be studied, which will be combined with the research done on the system's outflow piping, since the primary concern in that respect is where the effluent flows to and how fast it does so.

2. Impacts on Marine Habitats

Two more baseline studies need to be completed concerning local marine habitats, one pertaining to deep coastal water and one pertaining to the shallow water (Sinclair et al., 2011). The shallow water study should reach from +10 to -100 feet Mean Sea Level (MSL) and will primarily include an assessment of local coral, and whether or not there are any threats to the coral posed by construction and outflow from the system. The deep water research will examine the depths from -100 feet MSL down to approximately -2,500 feet MSL. This will concern the footprint of the sea water utility corridor, referring to the path of the pipe down to the seafloor (CH2M Hill et al., 2013). The study will examine the impacts of the system's moorings and anchors, as well as impacts on the coral reef. Special attention will be paid to the question of whether or not the outflow will have any adverse effects on the local reefs, although the depth of the outflow pipe will be set with the intention of minimizing any of those issues.

3. Impacts on Local Marine Life and Fisheries

Further, a biological consultation must be carried out regarding the effects of construction on other local fish and marine life. In accordance with the Magnuson–Stevens Act of 1996, no construction or action should be undertaken that has the potential

to accelerate the loss of a marine fish habitat. According to the law, the waters surrounding Guam are classified as an essential fish habitat (EFH), which means the habitat areas are rare, particularly susceptible to human-induced degradation, especially ecologically important, or located in an environmentally stressed area (NMFS, 1996). Given this specification, an EFH assessment will need to be carried out to ensure that construction of the SWAC system is not having an adverse effect on the waters in which it is located. If the system is found to have an impact, a biological assessment will have to be prepared in accordance with NOAA regulations.

4. Impacts of Returned Water to the Aquatic Environment

One of the largest and most obvious concerns regarding the implementation of SWAC has to do with the impact of the outflow from the system, and the concerns that accompany the release of what may be heated water back into the local ecosystem. Heated water, or water that is significantly hotter than its surroundings, being discharged from the system can adversely affect coral growth and have numerous other unintended consequences. As the NAVFAC has said in its feasibility studies, it should be assumed that the discharge return pipe will be set at a depth with a minimum temperature of 55°F, and this should not be harmful to the local coral environment (CH2M Hill et. al, 2013). In addition to the temperature, the noise produced by the system, both in construction and operationally, must be monitored to ensure that levels produced are not harmful to sea turtles and marine mammals. This monitoring may have an outsized impact on budget and time lost due to potential work stoppages, but that figure is impossible to quantify at this time.

C. POTENTIAL FOR LOCAL ACTIVIST OPPOSITION

In addition to all of these permitting and consultation issues, there are likely to be a number of private local groups interested in the construction of this system. Most activist groups in Guam tend to focus on the civil rights of individual Guamanians. However, a few will probably have questions about SWAC and concerns over its environmental impacts. Chamorro Nation, for one, is a local Guamanian group that makes its opinions known on any government project. Their status as a Guam separatist

group makes them instantly skeptical of the U.S. military and its aims. They have not yet made any objection to the construction of a SWAC system known. Groups such as these should be treated with respect and informed of the aspects of the construction should they ask about it. It is not thought at this time that local activist groups will have any problems with this project, but their concerns must be carefully addressed all the same.

D. CONCLUSION

The environmental vetting of this project is anticipated to be time-consuming and thorough. However, there is some relief that the system is designed with environmental friendliness in mind. In this case, the SWAC concept involves the intake and discharge of sea water in a body of water that has been designated as environmentally sensitive. It is part of the design of the SWAC system that unpolluted water be returned as effluent, and the pipes are also supposed to be carefully set so that the return water is released at a depth where there is little, if any, temperature differential. Being fully aware of the environmental hurdles involved in undertaking a project of this scope is essential to its successful completion. A two- to three-year window, as estimated by the NAVFAC, seems to be reasonable for this kind of project. The NAVFAC estimates an approximately $2.7 million price tag for this project’s environmental vetting spread out over a 30-month window (CH2M Hill et al., 2013). Although these estimates are subject to delays and issues, which are unseen at this point, this is the best cost estimate for the environmental concerns that must first be addressed.

IV. NAVAL BASE GUAM ASSESSMENT

A. SITE DESCRIPTION

Naval Base Guam occupies the Orote Peninsula of western Guam. A detailed base map from the NAVFAC is provided in Figure 6. A key question with SWAC is the location of the sea water intake and outtake pipes and associated sea water pumps.

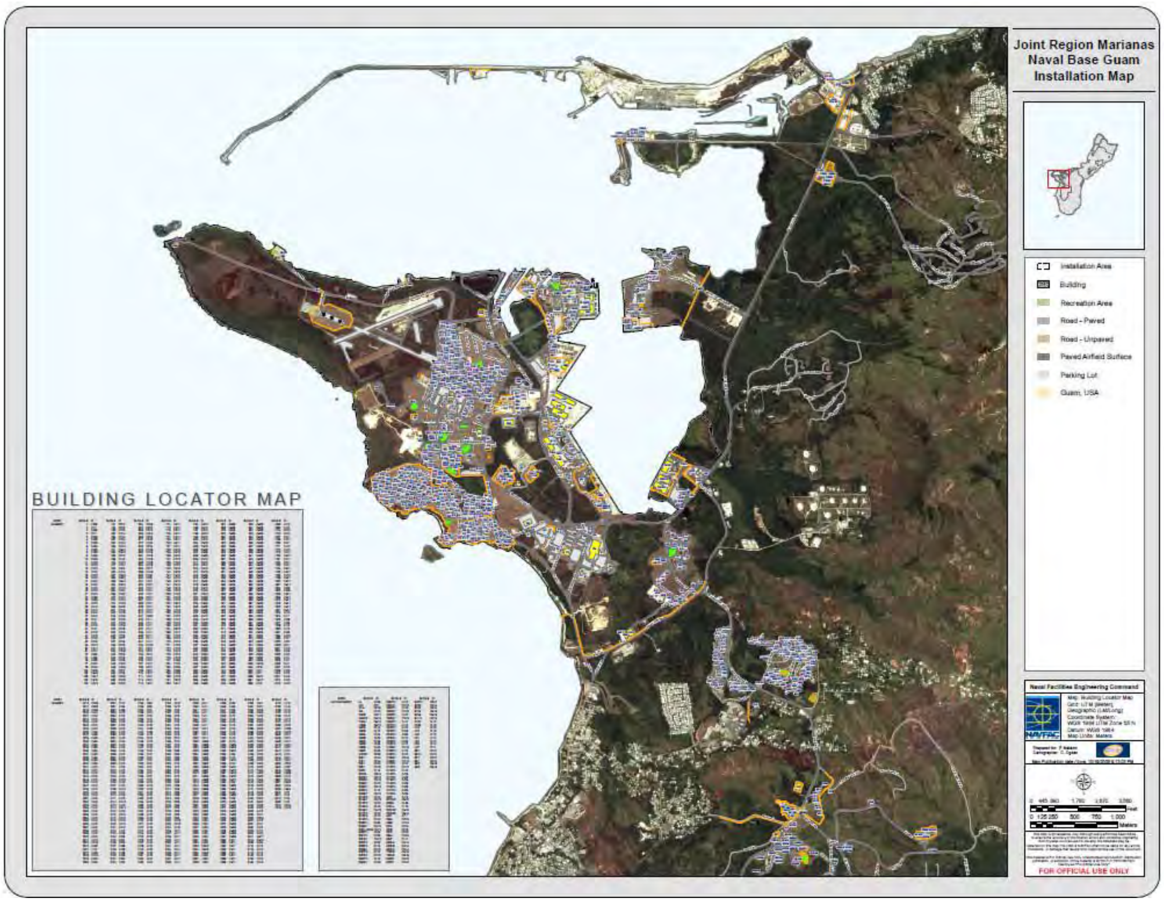

Figure 6. The Orote Peninsula (from Sinclair et al., 2011)

1. Shoreline Access

Since all proposed shoreline access sites are on government land on the Orote Peninsula, the NAVFAC foresees no potential easement issues (Sinclair et al., 2011).

2. Pumping Station Sites

There are four areas of Naval Base Guam designated as district cooling zones. The four black circles in Figure 7 represent these zones. Presently there are four proposed sites:

- Dadi Beach: This beach intersects with the red line in Figure 7. The red line represents the potential route of sea water intake and outtake pipes. Potential problems with this site include the presence of an ancient Chamorro village and World War II remains, specifically Japanese pillboxes and fortifications, directly behind the beach. The NAVFAC believes it can tunnel beneath these historical sites without damaging them. Dadi Beach would require the longest offshore pipe of all of the sites.
- Rock Quarry: A ridge shelters this site from storms but the rock in vicinity of Dadi Beach has karsts, which are underground drainage systems with sinkholes and caves. The risk with such geography is the drilling rig could fall into a sinkhole and be lost while tunneling beneath the surf zone, which according to NB Guam authorities has already occurred.
- Orote Landfill: This site is an old landfill that was closed and sealed after World War II. It is located at a break in the ridgeline, which provides easy access to the ocean, and has the added benefit of having little or no coral directly offshore, which mitigates some environmental risk. The landfill itself is deemed off-limits by base authorities, but the land directly around it is undisturbed and would support surface-level piping. This site is intersected by the orange line in the graphic, which represents the offshore piping route. The landfill is the closest site to the base cooling loads after the Rock Quarry.
- Kilo Wharf: Kilo Wharf is an ammunition loading area located on the northeastern edge of the Orote Peninsula where ships are loaded with explosives. This area could be problematic due to frequent ammunition loading operations that restrict access, the presence of coral offshore, and its relative distance from the four base cooling loads. Kilo Wharf would have the shortest offshore piping of the proposed locations (CH2M Hill et al., 2013).

Figure 7. The Four Proposed Cooling Districts (from Sinclair et al., 2011)

The third site mentioned previously in this section, the Orote Landfill, does not present any of the major cultural or environmental risks of the other three proposed pump station sites. In this particular site, an offshore pumping station would be ideal in order to prevent breaching the surface of the ground surrounding the landfill. Surface piping could connect the pumping station to a heat exchanger building located in vicinity of the rock quarry. The rock quarry is a convenient and economical site for the heat exchanger building because it is located near the two largest district cooling areas. Figure 8 illustrates possible pump station locations at the Orote Landfill site. The concrete block in the foreground represents the offshore location, while the two black squares represent alternate shore locations. The shore locations would have to be blasted out of the rock (CH2M Hill et al., 2013).

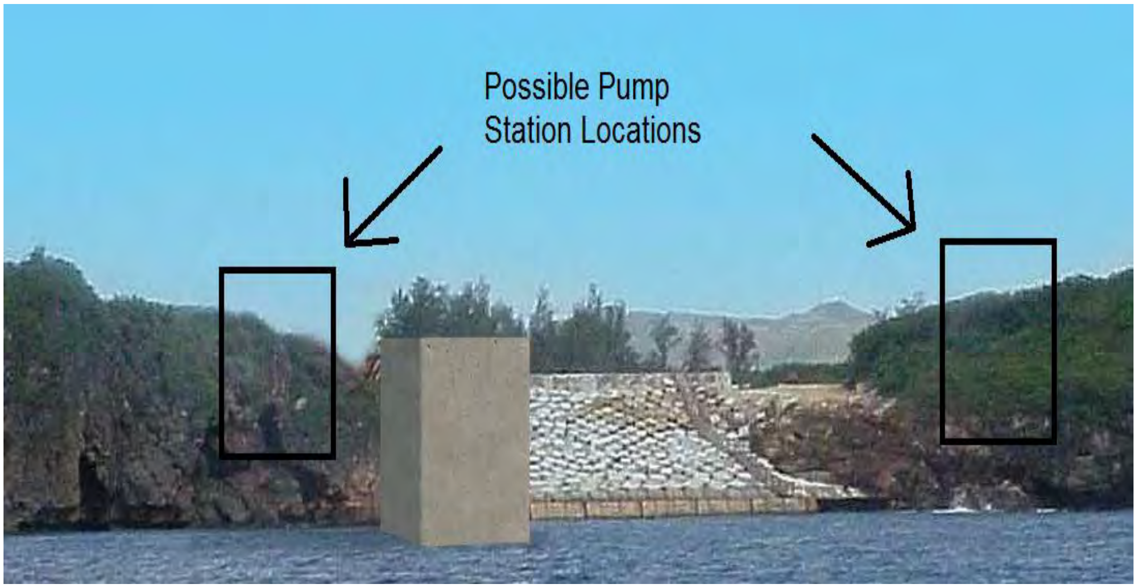

Figure 8. Orote Landfill Pump Station (from CH2M Hill et al., 2013)

3. Freshwater Distribution System

The freshwater distribution system would be a mostly underground, insulated closed loop that would deliver chilled water to existing building air conditioning systems. The proposed cooling load will include 169 base buildings and 578 housing units, and an expansion capacity of 800 tons AC without modification (CH2M Hill et al., 2013).

4. Offshore Intake and Outtake

Under the proposed SWAC design, sea water temperatures must be 43°F at the heat exchangers. At the Orote Landfill site, 43°F temperature sea water is found at a depth of 2,200 feet, requiring an intake pipe 13,300 feet long to achieve said depth. The sea water intake terminates at the sea water pumping station pictured above. After passing through the heat exchangers, the sea water temperature will be 55°F and will be returned to the ocean at ambient depth. 55°F ocean temperatures are found at a depth of 830 feet, about 3,000 feet from the shore (CH2M Hill et al., 2013). Figure 9 shows the detailed bathymetry where the proposed pipe will be installed.

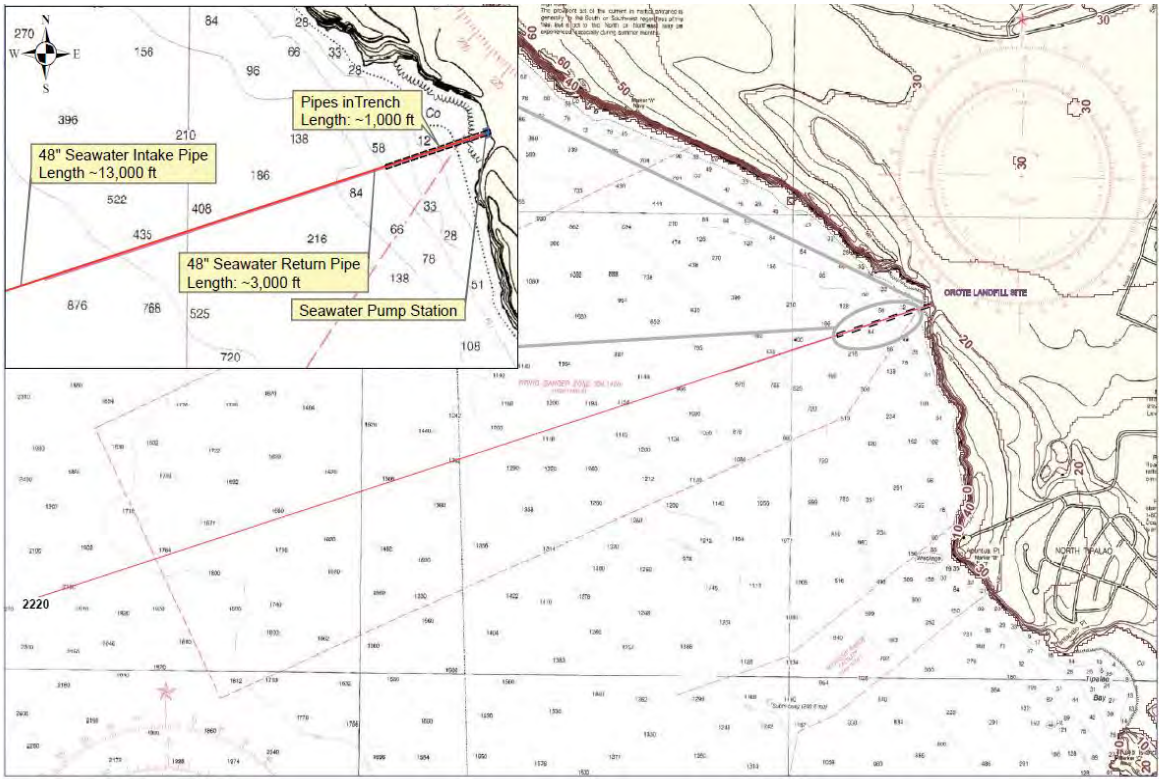

Figure 9. Orote Landfill Bathymetry (from CH2M Hill et al., 2013)

It is worth noting the offshore intake and outtake will cross the Tolofalo Fault Zone (Figure 10), which means the intake and outtake will need to be reinforced appropriately. Further studies are required to gain a better understanding of this offshore fault zone. Piping interference from shipping will not be an issue at the Orote Landfill site since the intake and outtake would fall entirely within the munitions range maritime exclusion zone (Sinclair et al., 2011).

Figure 10. Guam Fault Lines (from CH2M Hill et al., 2013)

B. COST ESTIMATION

Current SWAC cost estimation is based largely on three variables: piping, cooling infrastructure, and construction costs. Table 5 outlines these costs. For NB Guam, cost estimation assumptions are the following (CH2M Hill et al., 2013):

- SWAC construction will proceed using a competitive bid.
- Most building supplies will have to be shipped from the continental United States.
- Site access will be unimpeded for duration of construction.
- Contractors will not be unduly rushed, and there will be no overtime work.
- No security clearances required for labor.

The following are exclusions from the cost estimation:

- Unexploded ordinance (UXO) removal and disposal (common at NB Guam due to WWII UXO);
- Administrative, design, and legal costs;
- Schedule delays; and
- Changes to project timeline or location.

Table 5. SWAC Costs (after CH2M Hill et al., 2013)

Description	Amount
Chill Water Loop Supply and Return (Landside)	$25,445,040
Cooling Station	$22,177,600
Electrical	$16,440,186
Seawater Loop Intake and Outfall	$32,105,135
Pumping Station	$12,202,173
Purchased Equipment	$941,162
Total Construction Cost	$109,311,296
Total Tax Receipts (4.170% tax rate)	$4,756,633
Total Cost	$114,067,929

1. Existing Building Retrofit Costs

The SWAC system itself is not the only major cost estimation in this enterprise. All existing buildings on NB Guam that are to be cooled by SWAC must have their HVACs retrofitted. The buildings in their current configuration use three types of HVACs, but their details are outside the scope of this synopsis as they must all be replaced. The cost of doing so is forecasted by the NAVFAC to be $35.6 (CH2M Hill et al., 2013).

2. Estimated Construction Costs

The authors believe the maintenance of a backup chiller system is in the critical interest of NB Guam. While other studies list backup chiller maintenance as optional, the uncertainty inherent in the Navy's first SWAC installation justifies the expense of doing so; the principle vulnerability being the system's complete reliability on the structural integrity of the seawater intake piping. An unforeseen SWAC casualty that destroys the intake piping could bring the system down for weeks, according to NB Guam and NAVFAC officials. This would be especially problematic since large areas of base housing will be served by SWAC, whose many residents would have to be evacuated in the event of anything more than a short outage. A backup system can be achieved by maintaining the base's existing chillers and connecting them to the SWAC system. The total estimated construction cost for this back-up system is $163M, which includes the cost of maintaining a backup chiller system, retrofitting HVACs on existing buildings that will be served by SWAC, and the cost of constructing the SWAC system (Table 6).

Table 6. SWAC Total Estimated Start-Up Costs (after CH2M Hill et al., 2013)

Category	Estimated Cost
Sea Water Air Conditioning	$114,100,000
HVAC Retrofit Costs	$35,600,000
Backup Chiller Maintenance	$13,500,000
Total Estimated Cost	$163,200,000

Now that total construction cost has been estimated, the next step is to determine actual annual energy savings from installing SWAC at NB Guam. The first step is to determine annual kWh/yr consumed by the SWAC system, which is calculated by dividing the annual energy consumption of the SWAC pumping equipment by the annual hours of SWAC system operation.

3. SWAC System Energy Usage

SWAC energy usage consists of the energy required by sea water pumps to move sea water from intake to outtake, and the energy required to move chilled fresh water through the closed district system (Table 7).

Table 7. SWAC System Energy Usage (after CH2M Hill et al., 2013)

Usage	Expected Energy Consumption (kWh/yr)
Sea Water Pumps	3,431,262
District Chilled Water Pumps	3,239,472
Total	6,670,734

4. Utility Costs

NB Guam uses electricity supplied by Guam Power Authority (GPA) as its principal energy source (Sinclair et al., 2011). Utility costs are shown in Table 8.

Table 8. Utility Costs (after CH2M Hill et al., 2013)

GPA Utility	Unit Cost ($/kWh)
Electricity	$0.272

5. Energy Savings Summary

To calculate the proposed annual cooling cost, one takes total proposed pumping energy (6,670,734 kWh/yr) and multiplies it by the electricity utility rate. Subtracting the result from the given baseline annual cooling costs yields annual energy savings of $8,857,980 (Table 9).

Table 9. Annual Cooling Usage and Cost (after CH2M Hill et al., 2013)

	Annual Cooling Usage (kWh/yr)	**Annual Cooling Cost ($/yr)**
Baseline	39,236,818	$10,672,420
Proposed	6,670,734	$1,814,440
Savings	32,566,084	$8,857,980

This study does not consider escalation costs due to the uncertainly of the project timeline resulting from numerous factors subject to market conditions. Guam-specific market factors will influence the final cost of this project. Some of these factors are:

- fuel cost variability (shipping),
- availability of highly specialized craftsmen,
- availability of experienced local project management staff,
- local contractor workload, and
- commodity market variability (raw materials).

6. Life-Cycle Costs

The NAVFAC estimates a 40-year life for SWAC, but this study assumes a very conservative 20 years. At this point it is premature to attempt to forecast SWAC operation and maintenance costs, so this study assumes conservatively that these costs, shown in Table 10, will remain the same as the baseline operations and maintenance costs.

Table 10. Annual Costs in a 20-Year Life-Cycle (after CH2M Hill et al., 2013)

A/C Option	**Annual Capital Cost**	**Annual O&M Cost**	**Annual Electricity Cost**	**Annual Water Cost**	**Total Annual Costs**
Baseline	$0	$0.7M	$10.7M	$0.4M	$11.8M
SWAC	$8.2M	$0.7M	$1.8M	$0	$10.7M

Table 11 illustrates alternative SWAC life-cycle computations and how SWAC's initial capital costs are offset through reduced energy usage. Figure 11 shows the life-cycle cost over time for both the baseline system and SWAC.

Table 11. Multiyear Life-Cycle Costs (after CH2M Hill et al., 2013)

A/C Option	**Elec Usage (MW)**	**Elec Cost ($M/yr)**	**Capital Cost ($M)**	**10 Yr LCC ($M)**	**20 Yr LCC ($M)**	**30 Yr LCC ($M)**	**40 Yr LCC ($M)**	**50 Yr LCC ($M)**
Baseline	4.5	$10.7	$0	$107	$214	$321	$428	$535
SWAC	0.8	$1.8	$163.2	181.2	$199.2	$217.2	$235.5	$253.2

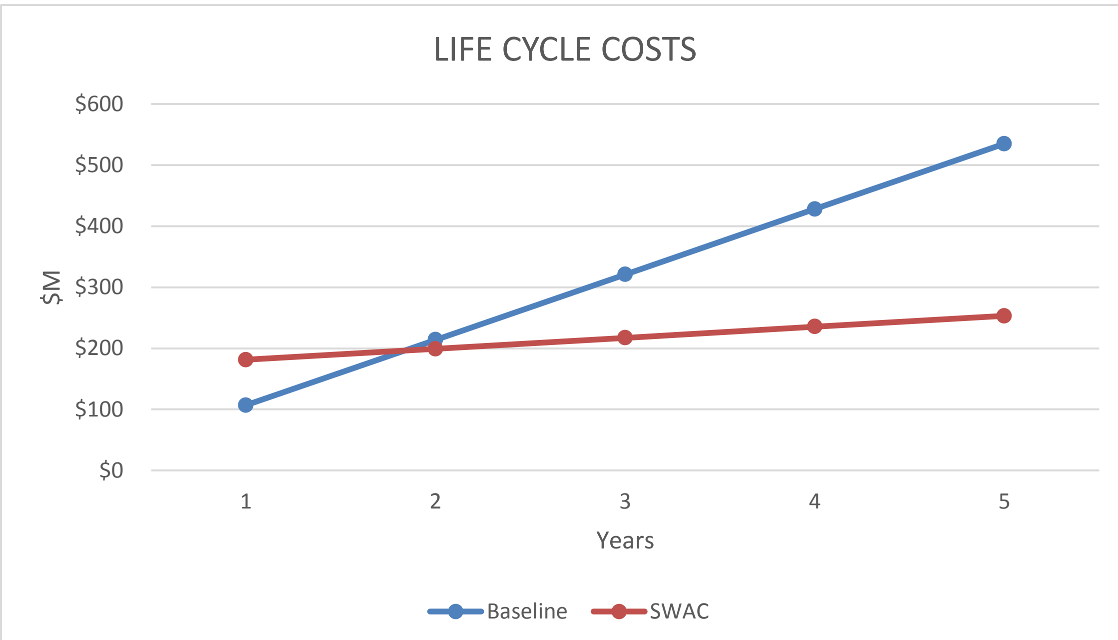

Figure 11. Life-Cycle Costs Over Time

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V. SYSTEM ACQUISITION STRATEGY

The purpose of the chapter is to investigate the proper strategy for acquiring SWAC at NB Guam. The acquisition strategy is a document developed by the program manager and approved by the milestone decision authority that outlines, at a high level, the business, contracting, and programming strategies the program manger plans to use to meet the objectives of the program (DOD, 2013; OUSD[AT&L], 2013). For the purpose of this report, the authors focus primarily on the potential funding methods, program management strategies, and scheduling.

A. FUNDING METHODS

In its study, the NAVFAC analyzes multiple potential methods for funding a SWAC system at NB Guam (Sinclair et al., 2011). The funding methods analyzed vary from the fully funded types of military construction (MILCON) and Energy Conservation Investment Program (ECIP) funds to the financed contract types of an energy savings performance contract (ESPC), utility energy service contract (UESC), and a power purchase agreement. This section provides a brief overview of each of the potential funding methods and then discusses in detail the ESPC, the best contract vehicle type and the one that the NAVFAC desires to use for SWAC.

1. Overview of Potential Methods

MILCON money is used to fund new construction projects via congressionally approved and appropriated funds. Operations and maintenance funds can only be used for minor construction projects up to $750,000 and $1,500,000 for construction to correct any threatening situation (Military Construction Codification Act of 1982, 2010). All other military construction must be specifically authorized by congressional legislation. However, the long timeline required to have individual projects approved and appropriated by Congress before construction can begin is a key disadvantage compared to some of the other funding methods (Sinclair et al., 2011)

The other potential appropriated funding method is funding through ECIP. ECIP is an energy-specific program managed by DOD within the MILCON portfolio. A key difference between ECIP-approved programs and MILCON programs is that the initial design effort will be funded by ECIP before receiving congressional authorization to obligate funds towards the construction (Sinclair et al., 2011). However, ECIP funding is limited. The current guidance for fiscal year (FY) 2016 ECIP submissions states that the annual budget is limited to $150,000,000 with only 65 percent of that amount ($97,500,000) going towards energy efficiency projects (OUSD[AT&L], 2014). In addition, of all the approved Navy ECIP projects in FY 2014, the highest annual project cost was $14,800,000 and the average cost of a Navy project was $3,880,000 (Office of the Deputy Under Secretary of Defense for Installations and Environment [ODUSD(I&E)], 2014). Therefore, the much higher cost of installing SWAC on NB Guam makes funding through ECIP infeasible.

An ESPC is one of the three financed contract types applicable to installing SWAC on NB Guam. An ESPC is a partnership between the government and a private sector energy service company (ESCO) via a performance-based contract. By entering into the ESPC, the ESCO is responsible for financing, designing, building, and maintaining the system for the length of the contract. The government pays the ESCO from the energy cost savings that are realized following construction of the system (CH2M Hill et al., 2013). The complexities and congressional mandates regarding ESPCs are explored more in depth in a following section.

A UESC is very similar to an ESPC except for one distinct difference. The UESC must be with the local utility company, which, in the instance of NB Guam, is the Guam Power Authority (GPA; Sinclair et al., 2011).

A power purchase agreement would be similar to a UESC in that the GPA would finance, design, build, and operate a SWAC system. In order to recoup its costs, it would sell the chilled water to the Navy to be used to cool the buildings. However, CH2M Hill et al. (2013) raised several points that would hinder the implementation of a power purchase agreement. First, it may be difficult for the Navy to convince the GPA to operate a district chilled water system because the energy savings from SWAC will most

likely reduce GPA's revenue. Also, GPA most likely lacks the financing required to fund the design and construction of the new system with no up-front payments from the government. These limitations of the GPA make both a UESC and power purchase agreement infeasible.

2. Energy Savings Performance Contract

The use of energy savings performance contracts (ESPCs) was originally authorized by the Energy Policy Act of 1992 (President, 2007) and was permanently reauthorized by the Energy Independence and Security Act of 2007 (2010). As stated before, an ESPC is a performance-based contract between the government and an ESCO. Because the ESCO finances, installs, and maintains the system during the term of the contract, the government needs no up-front capital costs to begin the energy savings project.

A key mandate in the Energy Independence and Security Act of 2007 is that the government's payments under the ESPC "may not exceed the amount that the agency would have paid for utilities with the ESPC" (2010, p. 6,588). This means that if the energy savings anticipated by implementing SWAC are not realized, the Navy cannot pay the ESCO more than it would have paid for utilities before SWAC, and the ESCO will have to absorb the design and construction costs of the new system. Therefore, the ESCO bears all the risk of a lower than expected energy savings, while the ESCO and DOD gain the benefits of higher than expected gains, thus making this type of contract "the best possible risk allocation for the federal agency and the taxpayer" (San Miguel & Summers, 2006, pp. 20–21).

However, there are three conditions in the codified law that can limit the use of ESPCs. They are the contract term length, the mandated measurement and verification, and limitation on existing buildings (Energy Independence and Security Act of 2007, 2010). The first paragraph of Title 42, Section 8287 limits the contract length of any ESPC to a period of no more than 25 years beginning on the date of the delivery order (Energy Independence and Security Act of 2007, 2010).

The law also mandates the use of measurement and verification tools to validate the amount of energy savings achieved. While a more robust measurement and verification plan will be more expensive to the government and reduce the overall cost savings of the project, requiring the correct amount of measurement and verification data from the ESCO is critical in determining whether the guaranteed energy savings is achieved (Sinclair et al., 2011).

Finally, the law directs that the energy savings from an ESPC must be achieved “in an existing federally owned building” (Energy Independence and Security Act of 2007, 2010, p. 6592). This means that the ESPC cannot fund the construction of any new facilities. Sinclair et al. (2011) acknowledged this limitation in their report and worried that it would prevent the use of an ESPC in the installation of SWAC on NB Guam since multiple new facilities must be constructed in order to install SWAC. However, the Department of Energy’s Federal Energy Management Program, which provides key expertise to help federal agencies their energy-related goals (DOE, n.d.), has released guidance on new construction under an ESPC. This guidance stipulates that new construction under an ESPC is prohibited except in two limited circumstances. This first, which is not as applicable to SWAC on NB Guam, is contingent upon the idea that a building is considered existing when there already is a viable design for its construction. Therefore, an ESPC can be used for implementing energy savings measures that would improve upon that design. The second, and more applicable, exception to the new construction prohibition, has to do with whether the new construction is necessary for the implementation of the energy savings measure. The Department of Energy’s guidance states that the construction of new facilities under an ESPC is permissible as long as “the construction is necessary for implementation, operation, and maintenance of an energy or water conservation measure” (2013, p. 2). The guidance uses a combined heat and power project as an example. The project might necessitate constructing a facility to house, operate, and maintain the large equipment involved. Because the construction of the new facility is required for the project to be implemented, the new construction is permissible (DOE, 2013). This example is directly applicable to SWAC. Because the construction of

the sea water pipeline, cooling station, and chilled water loop are absolutely necessary for the implementation of SWAC, the construction is permissible under an ESPC.

Due to all the before mentioned factors, an ESCP is the best contract vehicle to fund the design, construction, and implementation of SWAC on NB Guam. The period of performance for this contract should be no shorter than the time to construct the system and the estimated payback period but no longer than the congressionally mandated maximum of 25 years. To limit the risk of passing the 25 year maximum contract length and to maximize competition, the authors of this study recommend a competitive strategy for award of a firm, fixed-price contract for the design of the system and then re-competing the construction of that design with an ESPC. Although this analysis shows that an ESPC is the most efficient and effective funding method for SWAC, all options should be explored more thoroughly as more details of the project become apparent.

B. PROGRAM MANAGEMENT OF SWAC IMPLEMENTATION

In their article, Cantwell, Sarkani, and Mazzuchi (2013) cited many different challenges a program manager must overcome, from budget and schedule pressures to unstable requirements to inaccurate cost estimates. The installation and operation of SWAC on NB Guam will have all of these challenges and more. For the successful acquisition of SWAC, including operations and sustainment, the Navy must ensure the proper level and amount of program management and the associated oversight. To do this, one office must have the program management responsibilities of balancing performance, cost, and schedule in order to properly manage an integrated product team (IPT) whose primary goal is the SWAC's successful installation and operation.

The Navy Marine Corps Acquisition Regulation Supplement assigns contracting responsibilities for both facility construction and ESPCs to the NAVFAC (2013). Because the NAVFAC owns the requirement to reduce energy usage at NB Guam, it should have a major role in the management and oversight of the project. However, the installation commander will have the most insight into the needs and intricacies of NB Guam. Therefore, NAVFAC Marianas, which runs the NB Guam public works

department and is organizationally aligned with the NAVFAC but is located on NB Guam, is well suited for the role of program manager.

Almost as important as the individual managing the project are the members of IPT who work directly with the program manager. President (2008), who researched the successful use of an ESPC to implement a major energy savings project at Dyess Air Force Base (AFB), argued that the project would not have been successful without the collaboration and communication between all levels of management, the contracting office, civil engineering office, judge advocates, finance office, and the contractor (pp. 60–61). In order to replicate the success of an ESPC at Dyess AFB at NB Guam, the authors of this report recommend that at a minimum the following should be included in the program management IPT: public works officer (as program manager), energy manager, a contracting officer, civil engineer, finance officer, lawyer, and a representative from the contractor once the contract has been awarded. As shown in Figure 12, each of these members of the IPT, provided by either Naval Base Guam or NAVFAC, will report to the program manager.

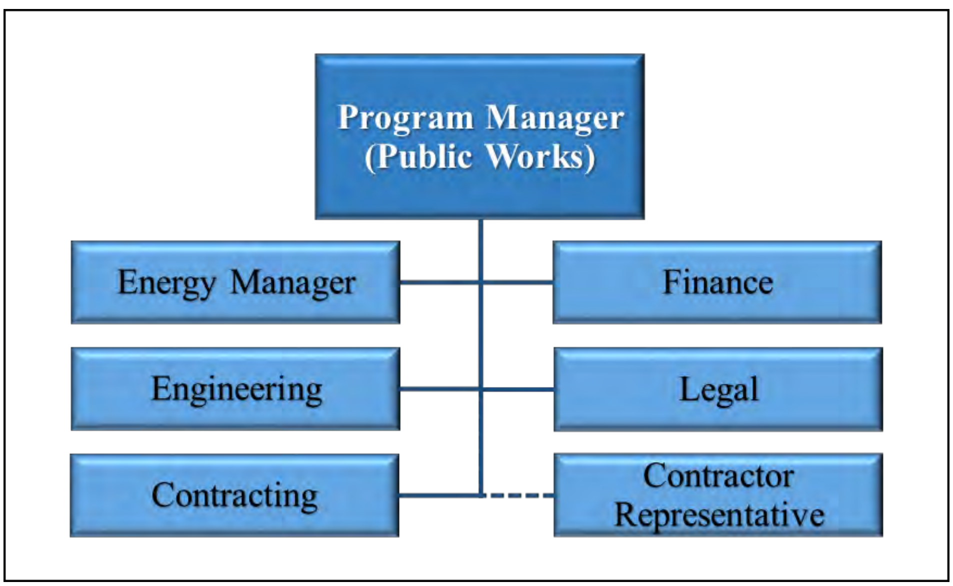

Figure 12. IPT Organizational Structure

C. NOTIONAL SWAC IMPLEMENTATION SCHEDULE (ACQUISITION AND ENVIRONMENTAL INCLUSIVE)

The schedule required to acquire SWAC should be examined and analyzed in more detail, but the overarching schedule is examined here. As discussed before, the environmental assessment is estimated to take 30 months to complete. For the purposes of this schedule, the authors assume that an EIS will be required. DeWitt and DeWitt (2008) conducted a study into the length of time required to prepare an EIS. While they noted that the time required in their sample varied from less than two months to over 18 years, the mean time required was 3.4 years. For the purpose of this study, the authors assume that an EIS will take 3.4 years to complete.

Because the authors recommend using an ESPC to fund the contract, a detailed design of the system can be accomplished concurrently with the National Environmental Policy Act (NEPA) defined environmental permitting process. However, construction cannot begin until all permits and NEPA requirements have been completed. Detailed design is expected be completed in one year with construction of the system being completed in two years (Makai Ocean Engineering, 2013; Sinclair et al., 2011). Figure 13 shows this timeline to include projected milestones and contract award dates. As shown in Figure 13, if the environmental planning begins by the third quarter of FY2015, April 2015, then the authors project that the construction of the SWAC system in Guam will be completed by the third quarter of FY2021, for a total schedule length of six years from initiation of environmental planning to completion of construction.

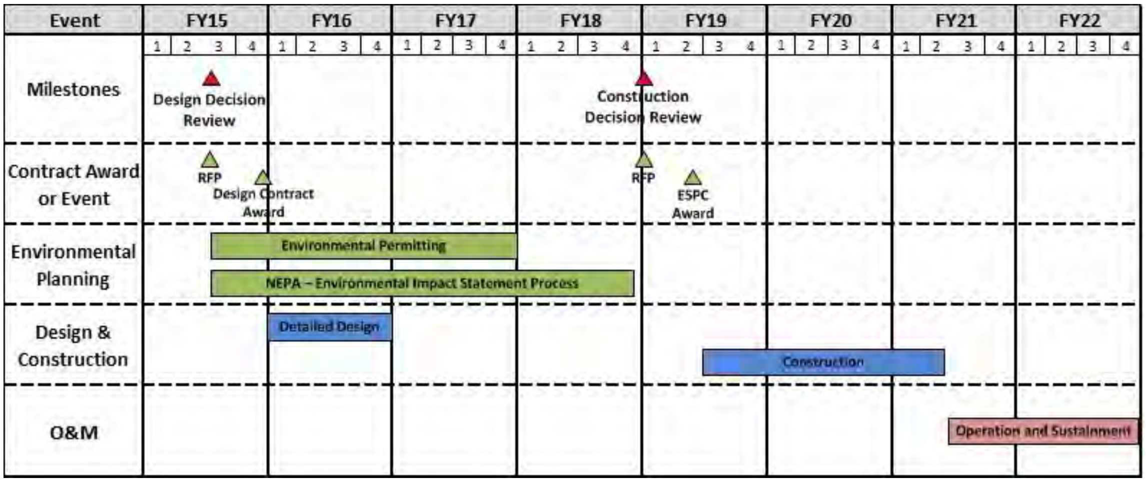

Figure 13. Notional SWAC Implementation Schedule

D. CONCLUSION

This chapter discussed the potential funding methods, program management structure, and schedule for the SWAC system. While there are many different methods for funding the design and construction of the system, an ESPC is the most effective choice because it does not require the large initial capital investment that MILCON and ECIP would require and places the majority of the risk on the contractor. For the success of the project, an IPT must be organized and comprised of all the necessary skill sets. Each of the identified members would report to the program manager. Finally, with the critical path including the environmental impact statement process and construction of the system, SWAC can be operational on NB Guam within six years from program initiation.

VI. RISKS TO SWAC IMPLEMENTATION

The implementation of a SWAC system is not without its risks. There are numerous areas of risk and unknowns involved in its construction and operation.

This chapter discusses the largest risk factors involved in the Guam SWAC project and evaluates them in a risk assessment matrix that evaluates the severity of risk for an event alongside the likelihood of the event's occurrence. This is a very easy-to-use technique that has been utilized by Naval Aviation, among many others, for the last two decades and has been successful in identifying and measuring many of the dangers and ambiguities involved with flying aircraft in a maritime environment. The matrix used is not an exact copy of the one used in the aviation community, having been adjusted to deal with the operation of SWAC instead of flying airplanes. The matrix is shown in Figure 14. Each risk factor is discussed and subsequently given a risk assessment code (RAC) to evaluate the scale of uncertainty posed.

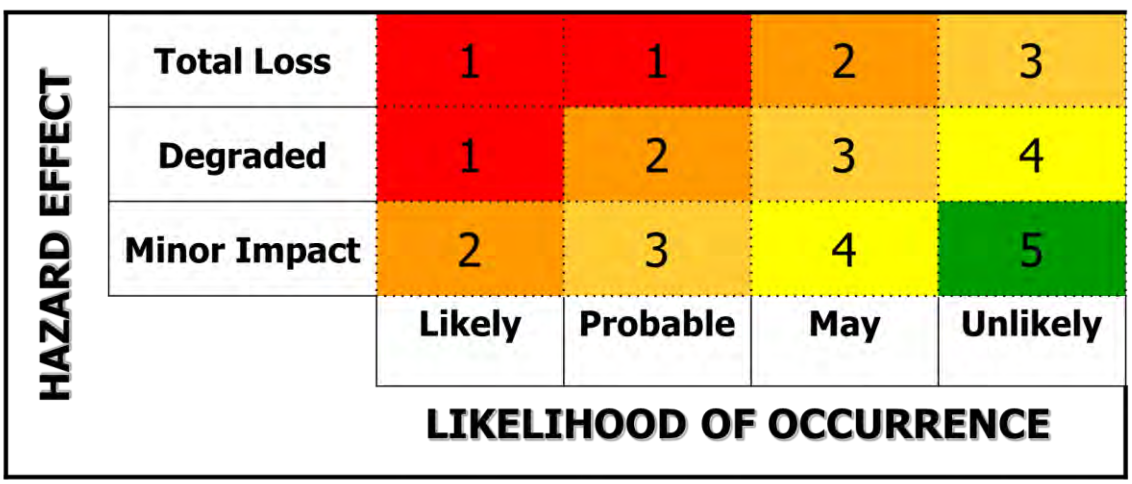

Figure 14. SWAC Risk Assessment

There are two broad categories of risk involved with this project, namely construction risk and operational risk. Construction risk refers to the unknown factors pertaining to the political process and building of the system. Operational risk refers to factors that come into play once the system is fully operational.

A. APPROVAL RISK

In evaluating the likelihood of the project being approved, one must consider the political forces surrounding the project. On the federal level, President Obama, and by extension, Secretary of the Navy Mabus, have made the "greening" of the Navy a very high priority. SWAC in Guam seems tailor-made for this initiative, given that one of the purposes for building it is to introduce to NB Guam a less resource-intensive method of keeping buildings cool. Given Secretary Mabus's emphasis upon integrating new and less fossil fuel–intensive energy systems into shore facilities (Department of the Navy, 2014) and the president's general affinity towards this type of clean energy project at the higher levels of government, the uncertainty concerning the approval of a project of this type should be fairly low. Additionally, although new to the Navy, SWAC is a proven method, in use around the world in a variety of climates and magnitudes. It is not a cutting edge, never before seen technology. It has been proven to be economically viable, and given the long term potential for cost savings and the high level political support this project should enjoy, the risk of the federal government disapproving the project is considered to be possible but unlikely. The authors assign this factor a RAC 3.

On the local government level, it is our opinion that the Guamanian government should have no serious objections to this project. Given that the project is intended to be environmentally friendly and that it will involve land and waters that are federally held to begin with, it is expected that local opposition to the project will be low, especially if the vendors building the system can find a way to involve local companies in some facets of system construction. The local power authority supports the project, so whatever objections they would potentially have for losing load provided to the base appears to be moot (GPA, 2005). If this were a project on private acreage or land owned by the Guamanian government, local opposition, especially from native activist groups, could possibly have been higher. But given that it can easily be presented as an environmentally friendly project overseen and paid for by the Navy, local objections should be at a minimum. The authors assign this factor a RAC 5.

If the project proceeds, the available funding avenues differ in the ways in which they assign risk. As discussed previously, it is likely that the funding will be in the form

of an ESPC, which is an excellent avenue to transfer risk from the government to the vendor. ESPCs shift most of the performance risk to the vendors, since they get paid out of the energy savings that their construction provides (San Miguel & Summers, 2006). If what the vendors make does not perform as they had predicted, the cost overruns and shortcomings in savings come out of the vendors' erstwhile profits. Vendor performance risk is fairly high here, but it is mitigated by the fact that SWAC is not a new, untested technology.

B. CONSTRUCTION RISK

Assuming project approval, the actual construction phase of this project is not without risk either. There will need to be construction and installation of the offshore piping, which is expected to be the most strenuous and labor-intensive part of the project. Onshore, the plan calls for the ground-up construction of a chiller building and a very large amount of on land ducting, most of which is going to be placed underground. Environmental and local permitting issues have already been addressed in a previous chapter, so providing that those are approved, the actual onshore construction process should be fairly straightforward.

There is some risk involving construction in the Orote Landfill area, given that the landfill contents have not been completely inventoried, and the possibility of unexploded ordnance being present in the area is high. However, the construction plans could easily bypass the area, especially if the ducting is routed along the edge of the landfill into space that is known to be free of unexploded ordnance. As long as this is adhered to, the risk of delay or injury involving construction in this area remains low. The authors assign this factor a RAC 4.

One interesting possibility concerning onshore construction, however, is the possibility, though faint, of artifact discovery during the construction process, as has happened on Navy bases in the past (Lagorio, 2006). This project will entail a large amount of on land excavation, and the Navy has a history of construction projects turning up historical artifacts and delaying projects for a significant amount of time. This risk of delay would be unlikely to completely end SWAC development on base, but does hold

the possibility of delaying construction for a long amount of time. The authors assign this factor a RAC 5.

The construction of the offshore piping is the more technologically challenging of the two broad construction categories. Even so, the risk factors involved with its fabrication and placement should be fairly moderate. Provided that the construction is paid for by way of an ESPC, the vendor will also have every motivation to be sure that the piping is well made and on schedule. Given that we again are dealing with a proven technology and that the vendor is most likely going to be a company that has done this type of construction in the past, the risk factors for offshore construction again come up low. The authors assign this factor a RAC 4.

C. OPERATIONAL RISK

Once operational, the portion of the SWAC system that will be most exposed to uncertainty is the offshore piping. Structural integrity of the system is the primary risk factor when dealing with this component, and the biggest problem the pipes are likely to face in this regard is the threat of severe weather. Guam is in a part of the Pacific Ocean that is commonly beset by typhoon activity (Guard, Hamnett, Neumann, Lander & Siegrist, 1999). And although the island has not been directly struck by a typhoon since 2002, that instance packed a heavy punch in the form of Super Typhoon Pongsona, which recorded sustained winds of over 125 miles per hour and caused widespread damage to the island's infrastructure (NASA, 2002). However, the wind is less of a problem for the pipe at water level than the surge and wave activity that accompany a typhoon. Makai Ocean Engineering, the primary vendor, touts the strength and flexibility of the piping it manufactures, but it does not advertise the piping's capacity to survive a direct hit from a storm the magnitude of Pongsona. The company also has not had its piping survive a direct hit from a major storm, although on its website it advertises having one of its pipes survive a glancing blow from a hurricane in Hawaii in the early 1990s (Makai Ocean Engineering, n.d.).

Given the extent of the damage caused in 2002 by Pongsona, and the historical scope of damage wrought by intense storms, it seems that a SWAC system offshore

would likely by totally disabled by a category five storm like Pongsona. If we assume a 25-year life cycle for a SWAC system and look at recent storm activity in the Guam region, it becomes likely that the island will see at least one major storm in is functional lifespan. A study by the University of Guam supports this, indicating that even though larger storms will probably be few and far between, smaller ones will continue to be common (Guard et al., 1999). This was proven correct by the devastation of Pongsona's direct hit in 2002, though Guam has not been struck by a super typhoon since.

Given Guam's location in the tropical Pacific, and the island's history of storm activity, it seems likely that the island will be hit by another significant storm in the SWAC system's lifespan. And though the system is designed to be quite resilient, it has to be expected that a category five storm will at least disable the offshore piping to the point of complete system failure. This puts typhoon activity at the highest possible risk level. The authors assign this factor a RAC 1.

There is also the threat of earthquake activity on Guam, but this as seen as a lesser threat to the system than large storms. The piping is designed to survive and operate in somewhat rough seas and storm surges, and the flexibility built into the piping's design backs up that claim (Makai Ocean Engineering, n.d.). These stresses would almost certainly be less than those encountered during a major storm, so the risk to the piping is judged to be less than that in case of a large typhoon.

Onshore damage in case of an earthquake could potentially be significant, but onshore repair in almost every case would be easier to access than offshore. Couple that with the stringent building codes enforced on Guam because of their regular earthquake occurrences, and the onshore risk of operation decreases by a good amount. It is an event that is probable to occur but will likely result in no more than partial degradation of the system. The authors assign this factor a RAC 2.

It is worth noting that the NB Guam Energy Manager plans to keep the current chiller systems in place at NB Guam, which in case of a large-scale SWAC outage would give the facility a backup system that can be turned on once power is restored to the base. The retention of the old system not only keeps the costs of implementing SWAC lower,

but also lowers the overall risk profile of day-to-day operation, which on its own is fairly straightforward.

In conclusion, the implementation of SWAC at NB Guam does entail a variety of different risk factors. But the addition of an environmentally friendly, off-the-shelf system such as this is on balance a very low-risk event. Although the SWAC system may be susceptible to extreme weather or earthquakes, it has been tested and proven to work worldwide. Overall, the risk profile is manageable, and the unknowns pertaining to its implementation should not be cause to stop or delay the project.

VII. CONCLUSIONS AND RECOMMENDATIONS

DOD must take all possible measures to ensure responsibility of allocated funds in the present environment of fiscal constraint. SWAC harbors the potential to save the Department of the Navy and DOD millions of dollars over the project's life. Implementing SWAC at NB Guam could save the Navy millions while also achieving energy goals set by the White House and Secretary of the Navy. While the up-front costs of SWAC system design and construction are large, an ESPC mitigates the need for investment capital by allowing the contractor to finance the design and construction while being paid out of energy savings once the system is operational. A program management structure must be established to provide the proper amount of leadership and management to control the performance, costs, schedule, and risk of the project. While the risk aspects of this project are not insignificant, they are manageable. As shown previously, each of the most likely/higher impact risks already have a mitigation plan in place.

A. SWAC RECOMMENDATIONS

Based on the research completed in this report, the authors have compiled several recommendations for NAVFAC and the Navy:

- Implement SWAC at NB Guam in order to potentially save the Navy millions in energy costs while meeting energy savings goals.
- Use an ESPC as the contract vehicle to fund SWAC. This method avoids massive up-front costs while incentivizing the contractor to maximize energy savings.
- Initiate environmental planning and the EA and EIS process immediately as they are the limiting factor in the schedule.
- Leave the existing air conditioning chillers and accompanying systems in place as a backup to mitigate structural failure risks due to natural disasters. These systems would be placed in layup to minimize maintenance costs.

B. RECOMMENDATIONS FOR FURTHER STUDY

While this study specifically focused on the use of SWAC at NB Guam and its associated costs, benefits, and acquisition strategy, there is plenty of room for related research. The following are recommendations for further study related to these topics:

- Recommend further research in other potential locations for the implementation for SWAC. The Air Force, Army, and Navy operate numerous facilities in isolated locations, near deep cold water, which could potentially be ideal opportunities for a SWAC system.
- Recommend examining other innovative, technologically advanced energy solutions for which the use of ESPC contracts might be appropriate.
- Recommend a study of other technologies in which the civilian sector is leveraged to reduce energy costs, and research their applicability to DOD.
- Recommend examining feasibility of ground-source cooling for DoD facilities in Guam

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